Introduction to Control and Some Instrumentation

Invited Presentation
Introduction to Mechanical Engineering

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Famous Canoe Example

Fig. 2. An unstable canoe.

Fig. 3. A canoe with an outrigger.

What is Control

To construct systems that **accurately** perform their intended desired tasks despite large **uncertainties**

Why is Control Needed?

Disturbances & Uncertainties

External and Internal

Major Objectives of a Controller

- Improved Performance - Specifications
- Lower Error (different types)
- Robustness (under different conditions)

Balance the 3 Objectives

Importance of objective is application dependent

Control System Goals

- Regulation
  - thermostat, flow of fluids
- Tracking
  - robot movement, adjust TCP window to network bandwidth
- Optimization
  - best mix of chemicals, minimize response times

Why Control Theory

- Systematic approach to analysis and design
  - Select controller based on desired characteristics
- Predict system response to some input
  - Speed of response (e.g., adjust to workload changes)
  - Oscillations (variability)

Typical Mechatronic products

Robots

Disk drives (video and CD)

Cameras and camcorders

Process controllers

Avionics

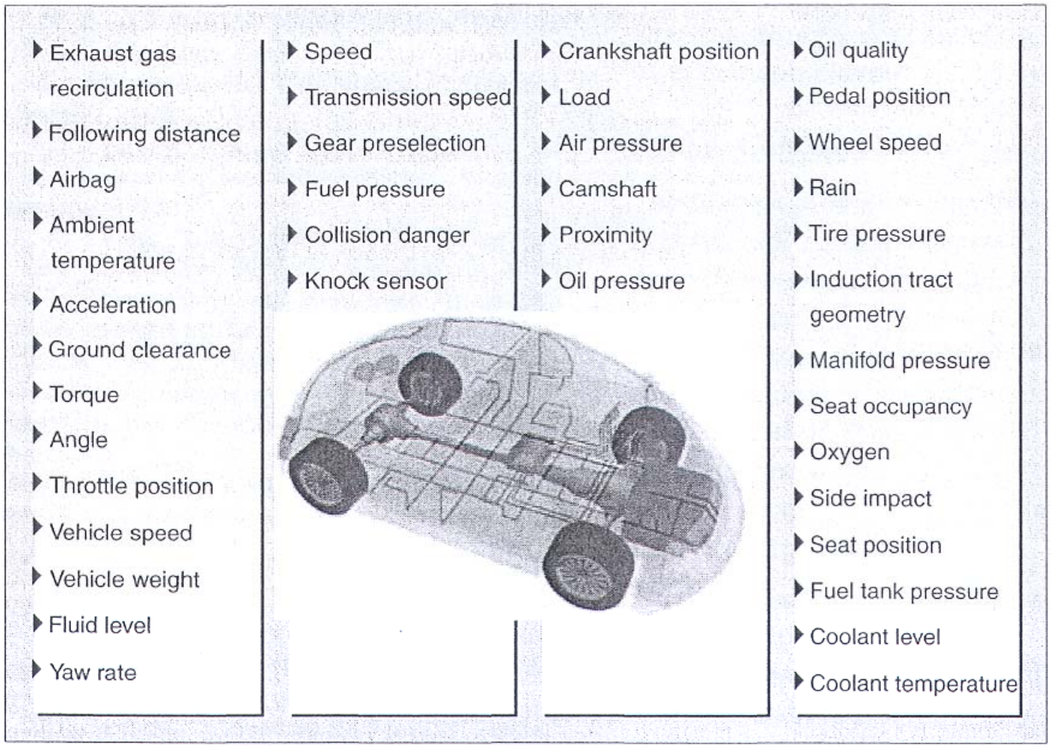
Appliances

Smart weapons

Power tools

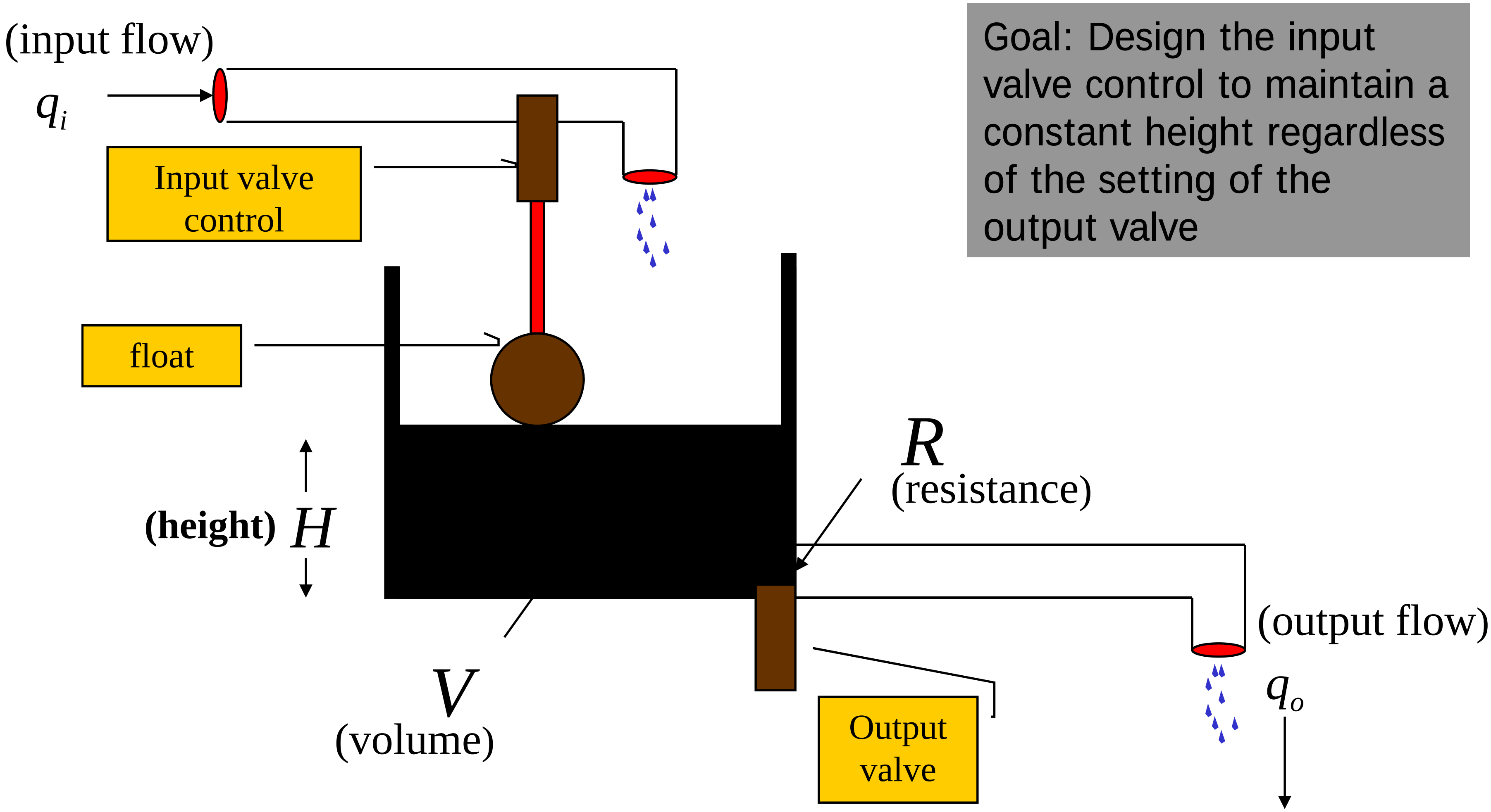
"Electronics Vehicle"

- engine controls
- anti-lock braking systems
- active suspension systems
- collision avoidance
- electronic muffler
- navigation, etc.



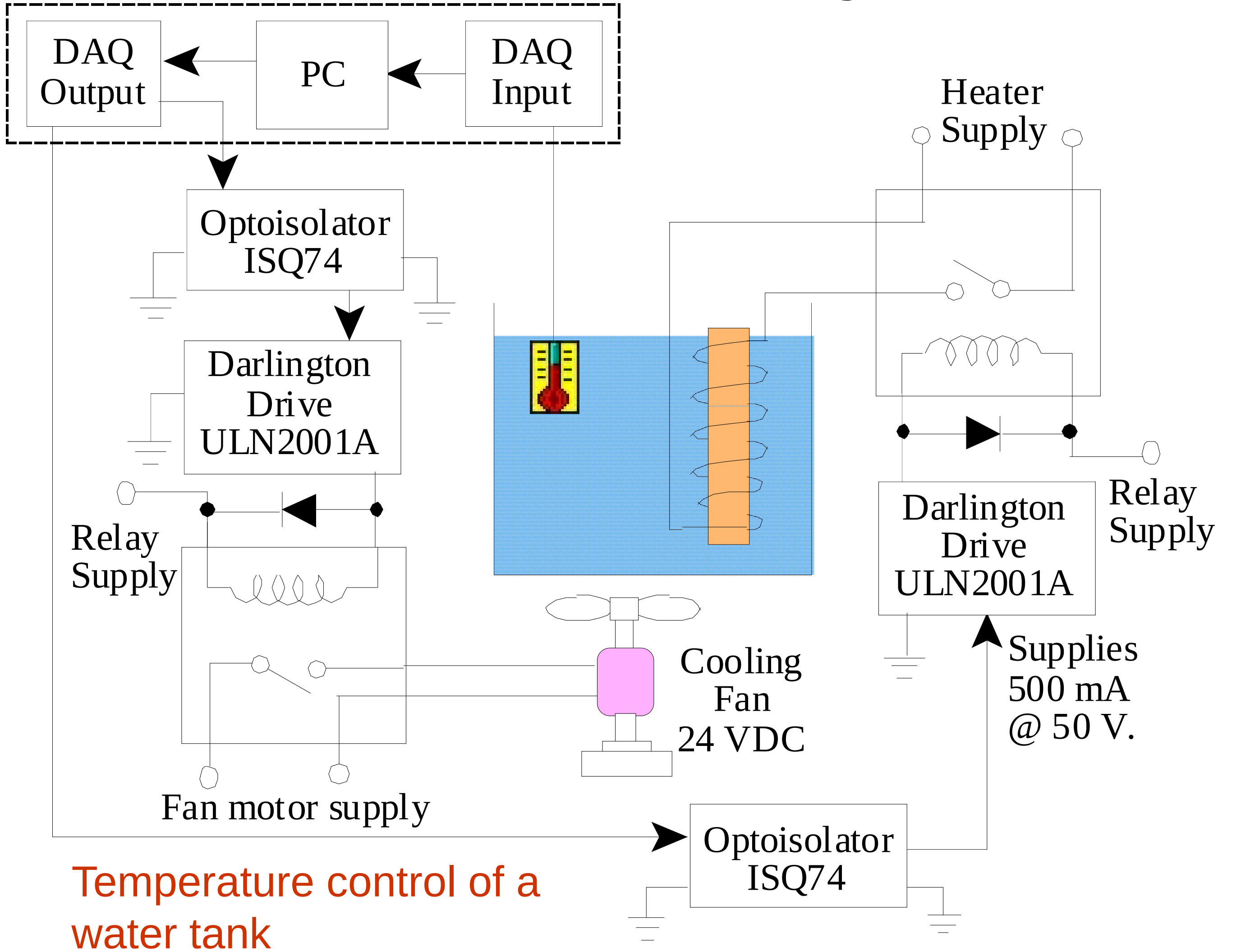
http://www.hybridcenter.org/hybrid-center-how-hybrid-cars-work-under-the-hood-2.html

Example: Liquid Level System



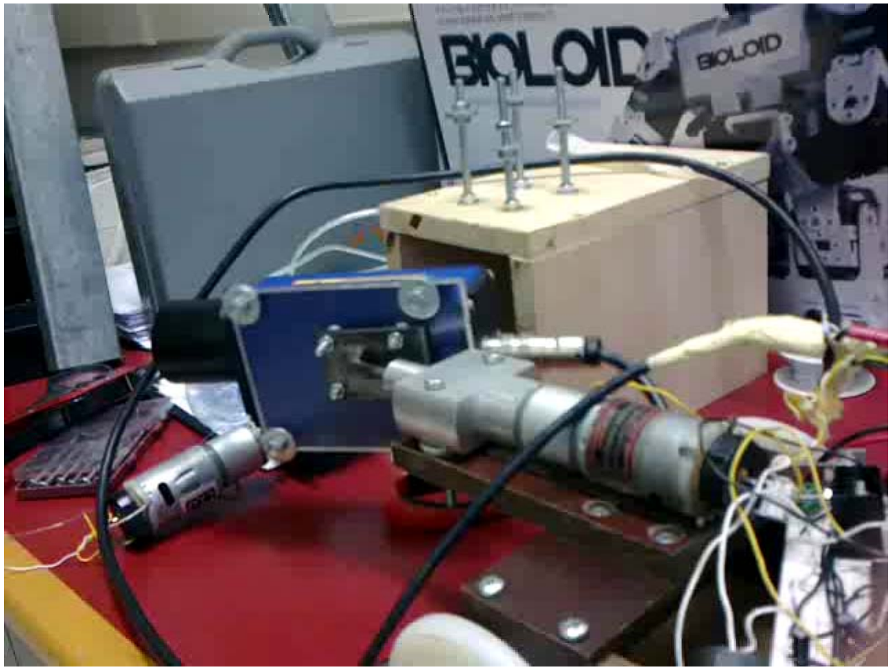
Goal: Design the input valve control to maintain a constant height regardless of the setting of the output valve

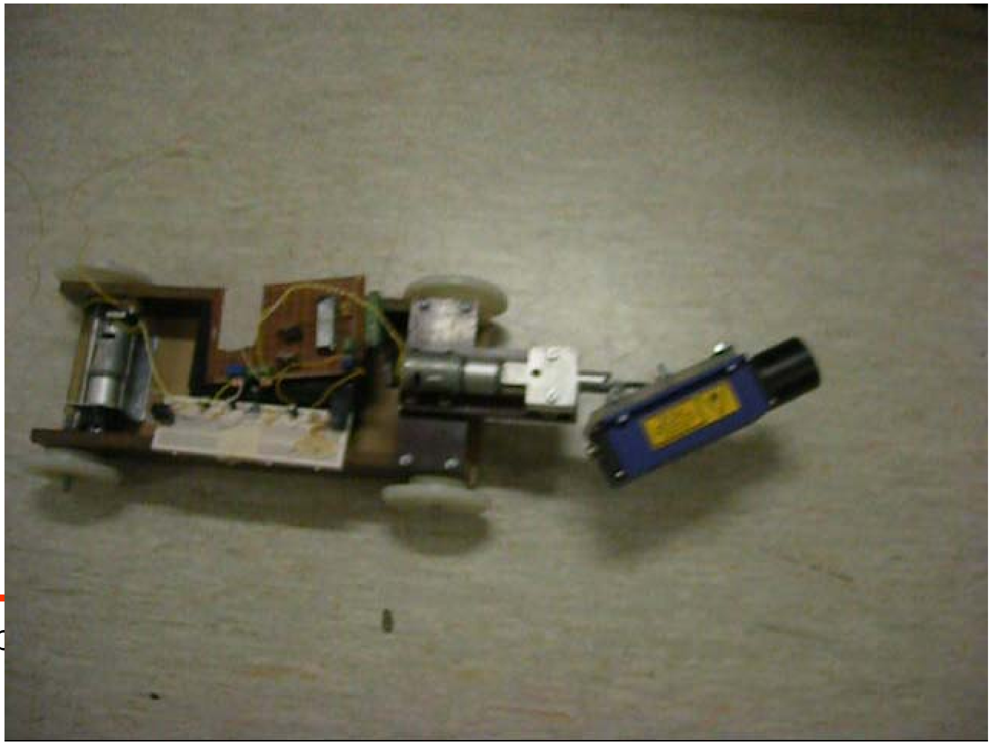
ON-OFF Control System



Temperature control of a water tank

Pipe Inspection Robot






HRP


HRP-1S: AIST Controller drives
a Honda Humanoid Robot
National Institute of Advanced Industrial
Science and Technology (AIST)
Kenji KANEKO
Fumio KANEHIRO
Kiyoshi FUJIWARA
Kazuhito YOKOI
Shuuji KAJITA
Hirohisa HIRUKAWA

Videos

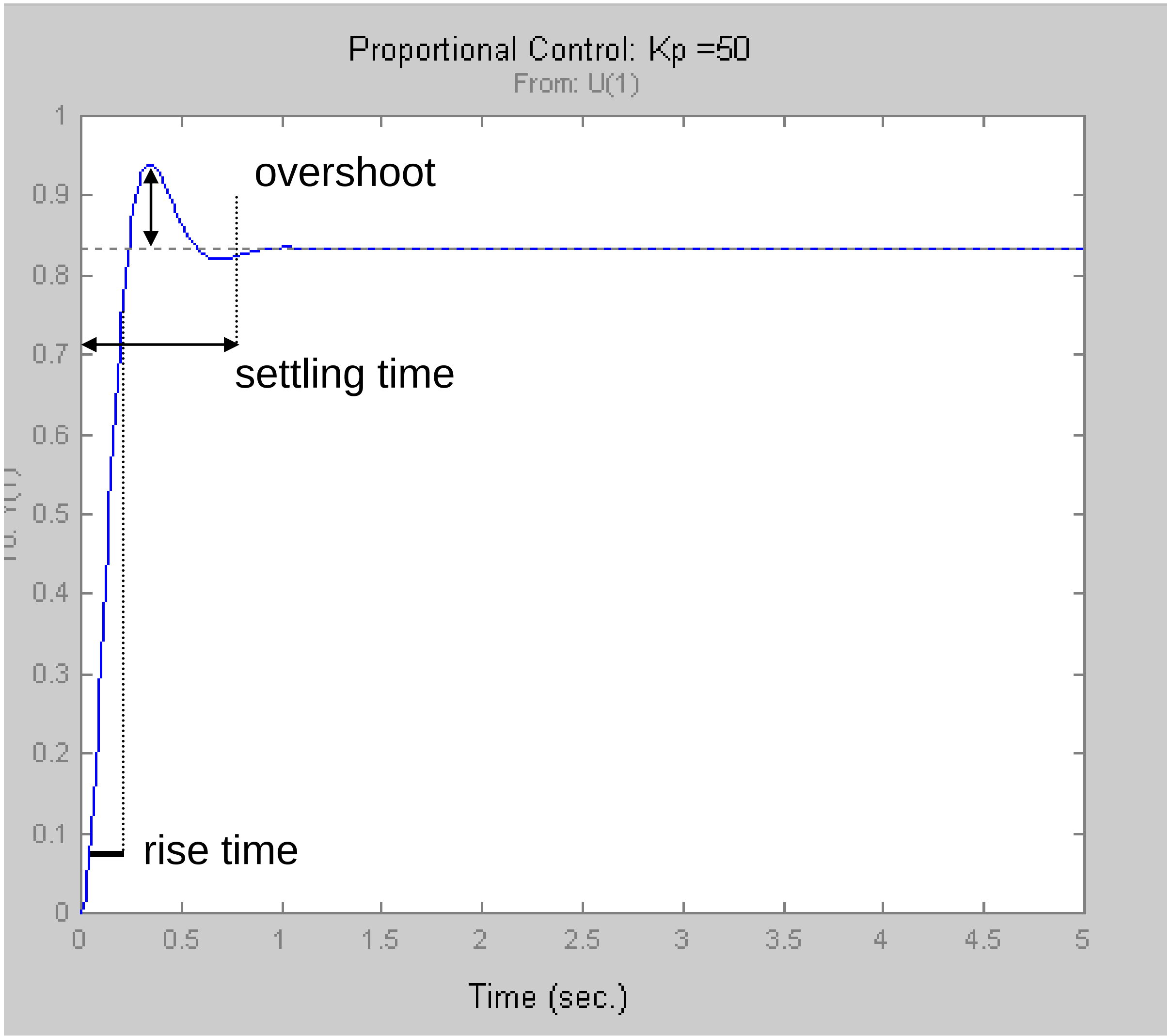
[ASIMO Dancing]

[Kung Fu Robots]

Brief Early History of Control

- 270 BC Greek Ktesibios invented a *float regulator* for a water clock
- In 800 through 1200 various Arab engineers used float regulators for water clocks and other applications
- The industrial revolution brought the need for automatic control
- In the mid 1800's mathematics was first used to analyze feedback control systems

Desired Output: Specifications - Standards



ss error -- difference from the system's desired value

overshoot -- % of final value exceeded at first oscillation

rise time -- time to span from 10% to 90% of the final value

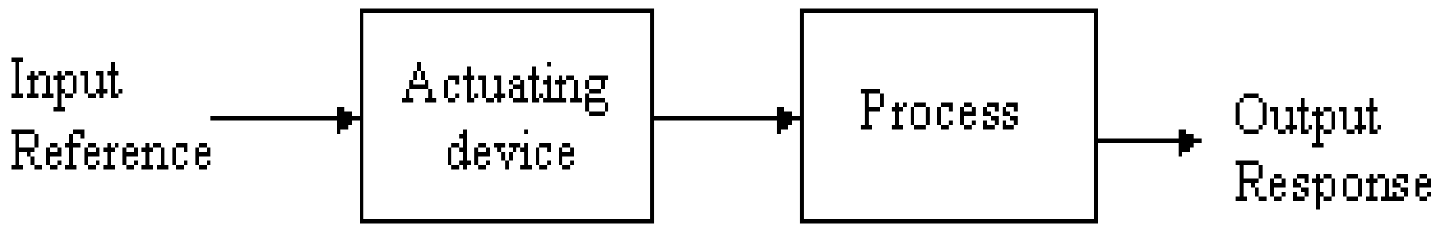
settling time -- time to reach within 2% of the final value

How can we eliminate the steady-state error?

Classification of Control Systems

- Open Loop
- Feedback Control
- Learning Control

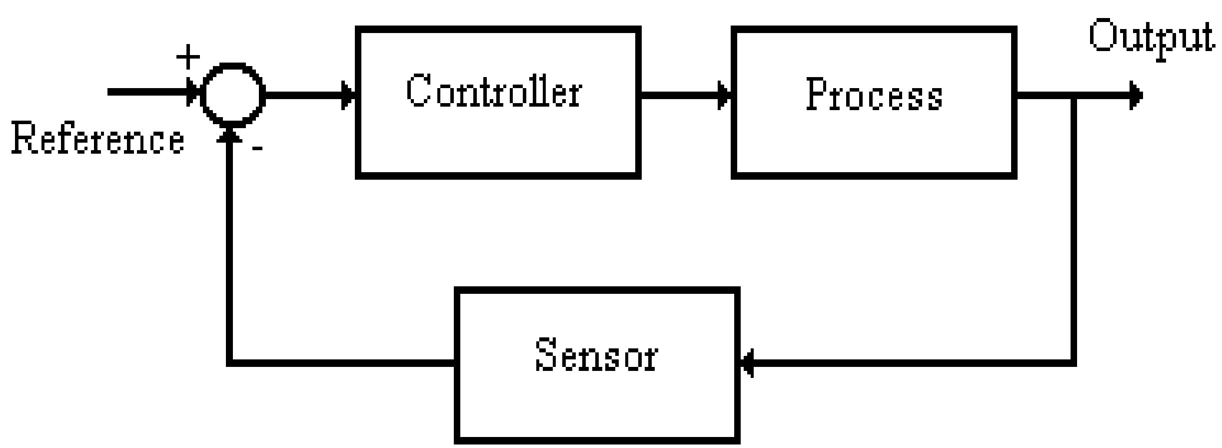
Open Loop Control



- Problem when external variations (load) or internal variations (friction) comes into effect
- A very accurate model of the system is needed

Closed Loop Control

- This setup will have a good disturbance rejection
- Closed loop control is used when unpredictable disturbances are present



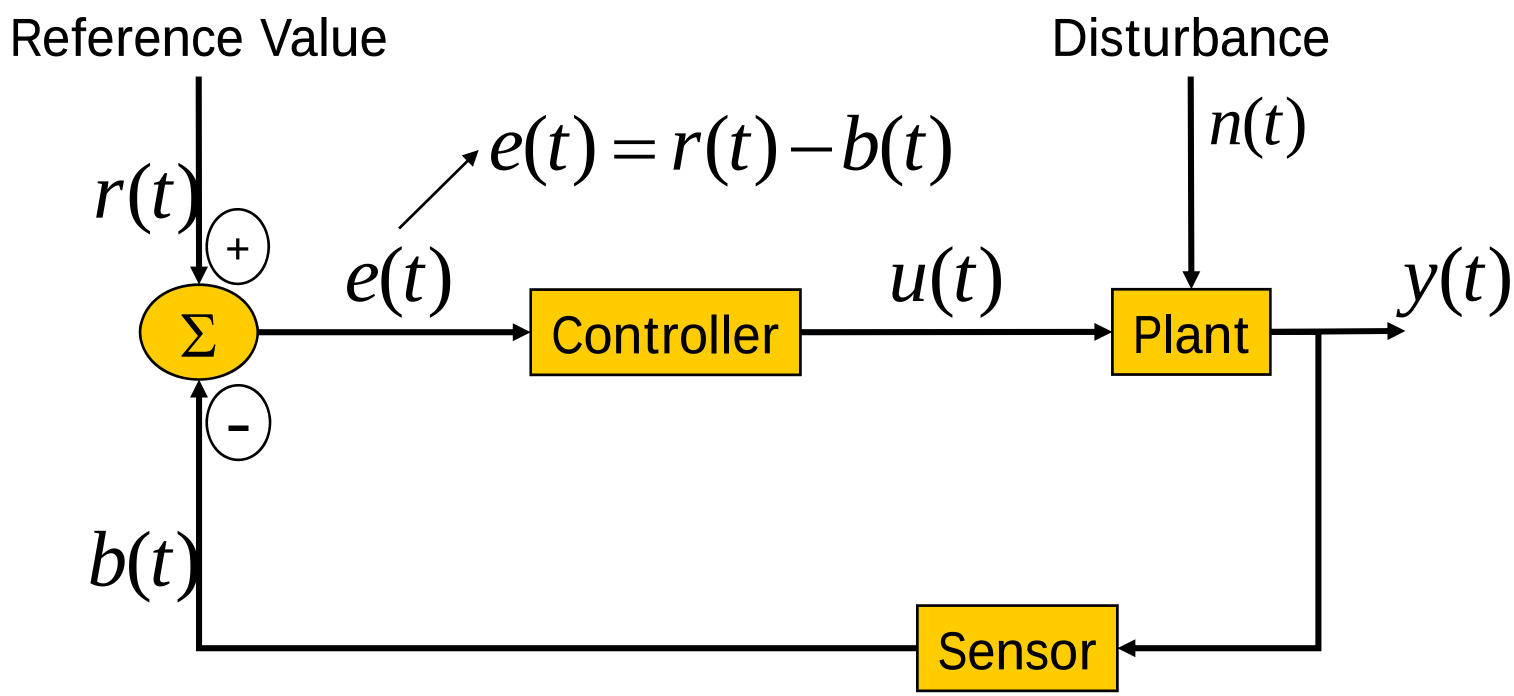
Mathematical Modeling

- Controlled devices are of electrical, mechanical, biological … nature
- A math model is needed describing behavior of the device in terms of input/output relations
- Model can be obtained theoretically
- Model can be obtained experimentally

Approaches to System Modelling

- First Principles
  - Based on known laws
    - Physics, Queuing theory
  - Balance between accuracy and complexity
- Experimental (System ID)
  - Statistical/data-driven models
  - Requires data
  - Is there a good "training set"?

Feedback Control System



Learning Control or Intelligent Control

- Humans can control highly complicated systems without the need for a mathematical model at all
- The goal of intelligent control is to emulate the behavior and structure of human expertise-knowledge.
- Uses various Artificial Intelligence approaches
  - Fuzzy logic
  - Neural networks (NN)
  - Machine learning
  - Genetic algorithms

Control Areas

- Theoretical
  - Controller design – Circuit/Algorithm
  - Modeling
  - Path planning
  - Intelligence
- Software
  - Interface, programming
- Hardware
  - **Instrumentation**
  - Processors
  - Control circuits
  - Actuators
- Integration
  - Mechatronics

Measurements

A measurement is the estimation of magnitudes of quantities relative to particular standardized quantities, called units.

Example:

Mass: 

0.5 Kg

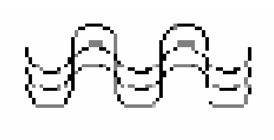
magnitude → 0.5 ; unit → Kg

Standardized quantity for mass: International prototype of the kilogram

http://physics.nist.gov/cuu/Units/index.html
National Institute of Standards and Technology

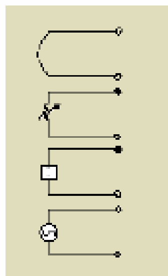
PC-based Measurement System

Physical phenomenon



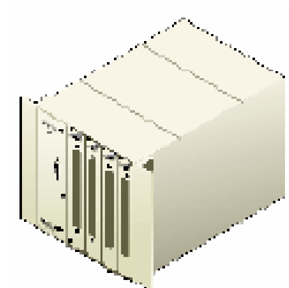
- -Temperature
- -Pressure
- -Displacement
- -Force
- -Light
- -Noise
- -etc..

Sensor (Transducer)



- -Resistive
- -Inductive
- -Capacitive
- -Light
- -Magnetic
- -Thermal
- -Ultrasonic
- etc..

Signal conditioning



- -Amplification
- -Linearization
- -Excitation
- -Isolation
- -Averaging
- -Filtering
- -Modulation
- etc..

Data acquisition

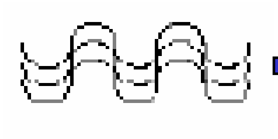
- -Analog multiplexer
- -Instrumentation amplifier
- -A/D, D/A conversion
- -Sample clock
- -Trigger

PC

- -Analysis
- -Feedback control
- -Display

Embedded Measurement System

Physical phenomenon



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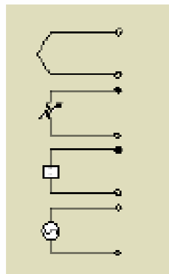

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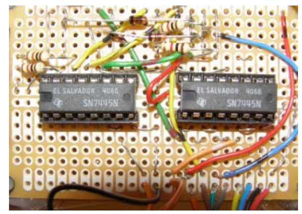

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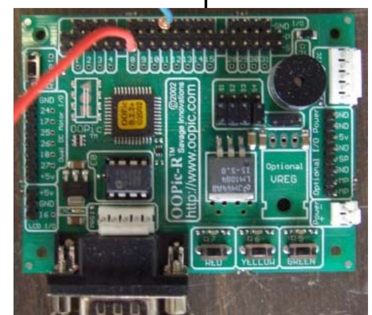

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Processing

-Analysis
-Feedback control
-Display

Transducers

- A transducer is a device that converts a signal from one physical form to a corresponding signal having a different physical form
- A transducer is an energy converter
- Different Types:
  - Mechanical
  - Thermal
  - Magnetic
  - Electric
  - Chemical
  - Radiation

Instrumentation Areas

Instrumentation is an engineering discipline that involves the study of:

- Signal conditioning
- Material properties
- Fluidics
- Heat transfer
- Mechanical properties
- Computer interface
- Electronics
- Modeling

AUB Courses Offered

- Undergraduate
  - EECE460 Control Systems
  - EECE460L Control Systems Laboratory
  - EECE461 Instrumentation (Includes Lab)
  - EECE462 Industrial Control (Soon)
  - MECH431 Control Systems
  - MECH431L Control Systems Laboratory
  - MECH430 Instrumentation & Measurements
  - MECH530 Mechatronics System Design
- Senior/Graduate
  - EECE660 System Analysis and Design
  - EECE661 Robotics
  - EECE662 Optimal Control
  - EECE663 System Identification
  - EECE664 Fuzzy Sets, Logic and Applications
  - EECE665 Adaptive Control
  - EECE 692 Nonlinear Control
- POPULAR FINAL YEAR PROJECT AREA

Questions?

Sources

- Some of the slides in this presentation taken from:
  - Joseph Hellerstein And Sujay Parekh, “An Introduction to Control Theory with Applications to Computer Science”, IBM T.J. Watson Research Center.
  - Jizhong Xiao, “Manipulator Control” Department of Electrical Engineering, City College of New York.
  - JM Geremia, “An Introduction to Control Theory From Classical to Quantum Applications”, course notes, 2003.
  - Ahmad Smaili, Fouad Mrad, “Applied Mechatronics,” Oxford University Press, New York, Feb 2007